

Chapter 23

Traffic Simulation of Kobe-City

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Abstract A traffic simulation of Kobe-city was carried out. In order to simulate an actual traffic flow, a road network was constructed utilizing a high-quality digital map data, and an origin-destination information of vehicles was estimated by a geographical population distribution data. The result obtained in this way was incompatible with the traffic census data due to the differences between the simulation and actual traffic, such as routing, OD information and so on. In order to improve the reproducibility of the traffic flow, the parameter search whose adjustable parameter was the speed limit of the road was conducted. This adjustment showed that reproducibility improves. Further improvement of the reproducibility needs to reconsideration of the routing algorithm.

23.1 Introduction

Cars and trains play major roles in today's urban mobility. According to a person trip survey of Keihanshin area [1], the percentages of car, two wheels, bus, railway, and walk in people's means of transportation are 33 %, 22 %, 3 %, 18 %, and 24 %, respectively. The percentage of the vehicle makes up a large fraction in the mobility. Therefore, it is not too much to say that people is living in automobile-dependent

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community. On the other hand, social problems such as the traffic jam are becoming a remarkable matter. These problems pose disadvantage to daily life, economics, global warming and other environmental problems. However, taking into account of risks and cost of a social experiment, it is difficult to conduct the experiment to resolve such problems.

A virtual social experiment which utilize a traffic simulation becomes a way to resolve these problems, because today's computer has a performance to execute a large scale simulation in a practical time. In this study, we focused on a traffic of Kobe-city as a specific example, and the traffic simulation of Kobe-city was carried out as a first step to resolve the social problems. Our purpose is to reproduce the actual traffic of Kobe-city as far as possible. When an actual traffic in Kobe-city is reproduced by the simulation, it will be possible to use optimization of a traffic system. In addition, this simulation will also be a basis for a simulation about a flow of people. Because, as mentioned in the beginning, traffic flow plays an important role in the people's means of transportation.

To simulate the actual traffic of Kobe-city, the road network and the traffic volume of Kobe-city have to be reproduced. Although almost all these kind of the simulations have used the OpenStreetMap (OSM) [2] for convenience, the OSM is not necessary sufficient in our purpose. Therefore, to attain the former, a high-quality digital map data was used. In order to realize the latter, we have to find an appropriate scenario and optimal parameters. In this study, only an attendance of the people was assumed as a traffic demand, and the speed limit of the road was chosen as an adjustable parameter. The results are compared with the traffic census data [3], and we discuss the variation of reproducibility by changing the adjustable parameter. We conclude this paper by commenting on the possibility of our parameter search.

23.2 Method

Although various traffic simulators exist, the SUMO (Simulation of Urban Mobility) [4] was adapted because it is fast enough to execute a large-scale traffic simulation whose road network size and the number of vehicles are large in a practical time. A method of the traffic simulation utilizing the SUMO consists of constructing a road network and estimating an origin-destination (OD) information of the vehicles. We are planning on carrying out the simulation of whole Kobe-city finally, a simulation in an area of mesh code of 523501 was conducted first to establish a methodology which reproduce the actual traffic flow. This is because, as far as we know, there are no general methods to do data assimilation with the actual traffic flow in the large-scale road network.

23.2.1 Road Structure

The purpose of this study is to reproduce the actual traffic of Kobe-city. For this reason, as mentioned in the previous section, utilizing the OSM was avoided because the OSM has more than a little difference from an actual road structure. For example, the number of traffic lanes and structure of the traffic intersection are different from actuals (see Fig. 23.1), and unrealistic isolated traffic lanes exist. In order to construct the actual road network of Kobe-city, a high-quality digital map data provided from Zenrin Co. Ltd. was used. The detailed data of the road network was converted to a format of an input data of the *NETCONVERT* [5] which is attachment program of the SUMO by our own script code of the Ruby. The resultant road network of mesh code of 523501 is depicted in Fig. 23.2.

23.2.2 OD Information

Because there was no available data about the OD information of Kobe-city, this was estimated by a geographical population distribution data estimated by NTT DoCoMo, Inc. from its mobile phone position data. In the geographical population distribution data, Kobe-city was divided into the meshes of 500×500 m, and the population of every 4 h for each mesh in a normal weekday was described.

We assumed that the distribution of the OD is proportional to the population distribution, and people is in a home in the mid-night (00:00 ~ 04:00), and in a workplace in the daytime (12:00 ~ 16:00). The *ActivityGen* [6] which is an

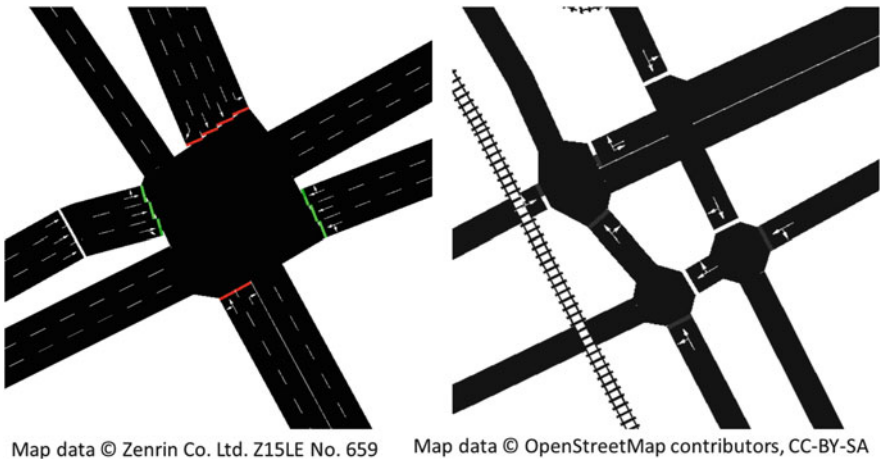


Fig. 23.1 Comparison of the road network of traffic intersection at Naka-koen-minami between Zenrin's and OSM's data. *Left panel* and *right panel* show road network constructed using Zenrin's data and OSM's data, respectively

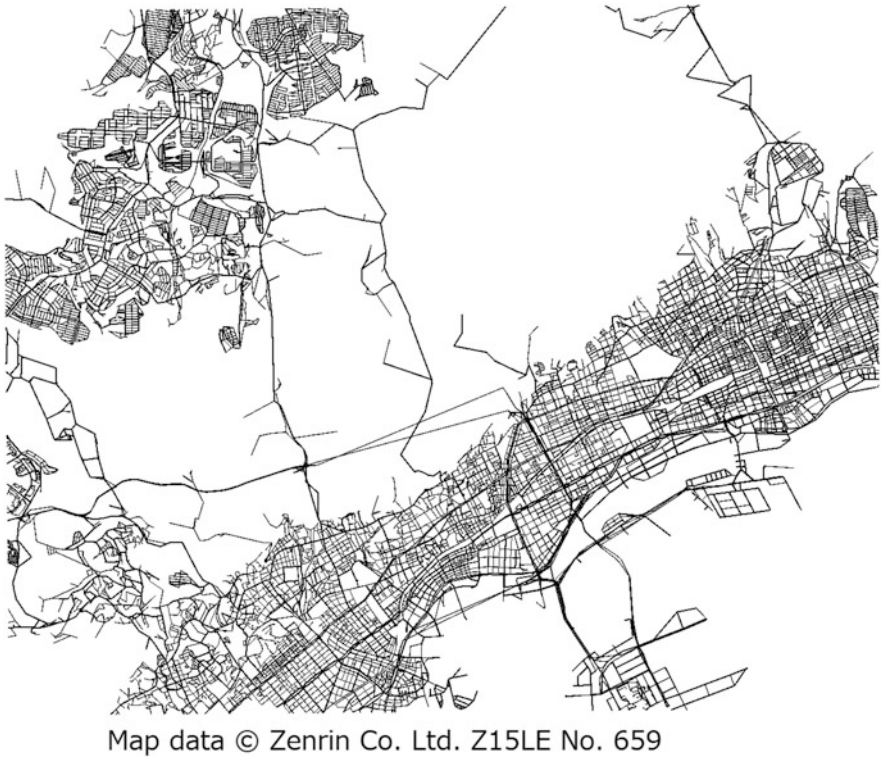


Fig. 23.2 The road network of mesh code of 523501

attachment program of the SUMO generates the traffic demand based on people's activity from the distribution of the people's home and workplace in the map by some statistical algorithm. We used this program to generate the OD data.

23.2.3 *Simulation*

The simulation utilizing the SUMO was carried out by using the road network and the OD data prepared by foregoing method. It is necessary to construct a route for each vehicle before executing simulation. In this study, the *DUAROUTER* [7] which is an attachment program of the SUMO was used to determine the route of the vehicle. This program searches a minimal traveling time path between origin and destination on the map by the Dijkstra method [8].

Since the route cannot be changed dynamically in the simulation of the SUMO, a glidlock results from the congested traffic. Therefore, iterative computation which repeats searching the route of each vehicle and simulation to run each vehicle was

performed to find a route whose traveling time is minimum. The *DOUAI*TERATE [9] which is attachment program of the SUMO was used to this end. This program does iterative computation so that the travel time of the vehicles attain minimum. In this study, the number of iteration was set to five times.

A scenario of the traffic simulation in this study is as follows. Only attendance was assumed as a traffic demand. The OD (the origin is the home of people, and the destination is the workplace of people.) was estimated from the geographical population distribution data as mentioned above. The total number of vehicle N is one of the adjustable parameters in this treatment. We set it to 100,000 per one day by reference to the traffic survey [10]. In addition, incoming traffic and outgoing traffic from out of the map of 523501 were ignored. The measurement of the traffic volume of the road was performed in a period of 7200–10,800s. We assumed for the first 2 h the preparation period to set up the vehicle on the map.

The results obtained in this way are compared with the traffic census data of Kobe-city [3] in the next section. We emphasize that the data assimilation of the traffic flow is challenging because there are many free parameters and the response to the parameter change is nonlinear.

23.3 Results And Discussions

To make a comparison between the simulation result and the traffic census data of Kobe-city [3], the number of vehicles which passed a point where the traffic census measurement was performed [11] was counted in the simulation. The points where the traffic census measurement was performed were categorized into three types. One is on the national route, another is on the prefectural road, and the other is on the city road. The results is depicted in Fig. 23.3. As seen from Fig. 23.3, the overall traffic volume of the simulation is less than that of the traffic census data in each kind of point.

From this result, we considered that the OD model and/or the route of the vehicle were needed to improve. However, it is difficult to improve the former because there is no available data about the OD information, as mentioned before. In addition, even if the distribution of the OD was changed, the result differed only slightly. Therefore, we focused on the improvement of the latter. The simplest way to change the route of the vehicle is varying the speed limit of the road. Because we used the Dijkstra algorithm whose weight of the road is traveling time of the vehicle. In fact, the result when the speed limit of the thin road is changed from 60 km/h to 3.6 km/h is depicted in Fig. 23.4. The difference between Figs. 23.3 and 23.4 is subtle. However, in Fig. 23.4, the green points near 300 in abscissa axis are approaching the diagonal line compared with Fig. 23.3. Therefore, we expected that the data assimilation is attainable by the adjustment of the speed limit of the road.

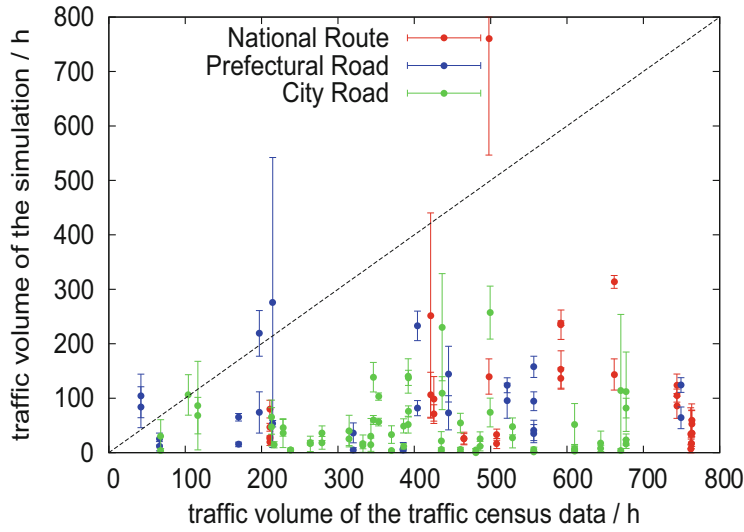


Fig. 23.3 The traffic volume obtained by the simulation is plotted against that of the traffic census data [3]. The results of the national route, the prefectural road, and the city road are depicted by *red*, *blue*, and *green*, respectively. The *error bars* show the standard deviation. The speed limits of each roads are set to the legal speed in Japan

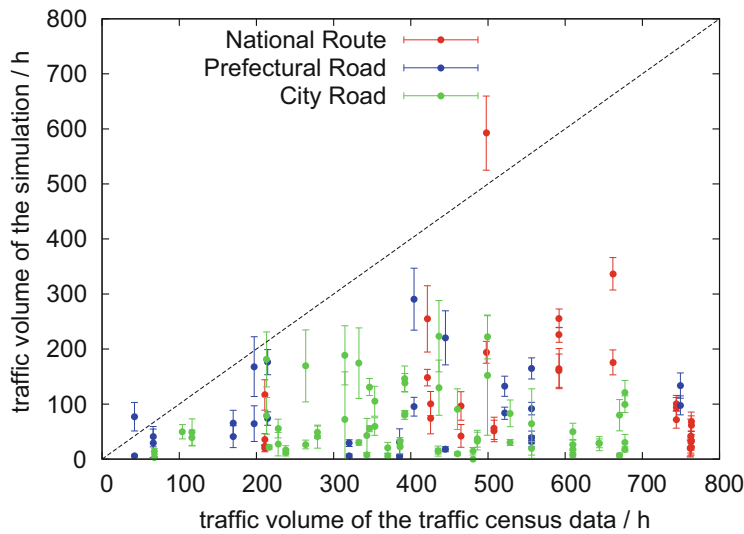


Fig. 23.4 The traffic volume obtained by the simulation is plotted against that of the traffic census data [3]. The results of the national route, the prefectural road, and the city road are depicted by *red*, *blue*, and *green*, respectively. The *error bars* show the standard deviation. The speed limits of each roads except for the thin road are set to the legal speed in Japan. The speed limit of the thin road is set to 3.6 km/h

To find a optimal set of the speed limit of the road, a loss function was defined as

$$F_{\alpha} = \sum_{i=1}^{N_{\alpha}} \left(\frac{f_{i\alpha}^{\text{sim}} - f_{i\alpha}^{\text{exp}}}{f_{i\alpha}^{\text{exp}}} \right)^2, \quad (23.1)$$

where $f_{i\alpha}^{\text{sim}}$ and $f_{i\alpha}^{\text{exp}}$ denote the traffic volume obtained by the simulation and the traffic census data at the i th measuring point on the road whose type is α . N_{α} represents the total number of measuring point belonging to the road whose type is α . In the area of the mesh code of 523501, $N_{\text{national route}}$, $N_{\text{prefectural road}}$, and $N_{\text{city road}}$ are 39, 26, and 64, respectively. As mentioned above, the speed limit of the road was chosen as an adjustable parameter, and the loss function was calculated to each parameter set.

The loss function of the national route, the prefectural road, and the city road are plotted against the speed limit of the national route in Figs. 23.5, 23.6, and 23.7, respectively. Figure 23.5 shows that the loss function decrease with the increasing the speed limit of the national route, and decrease with the decreasing the speed limit of the thin road. The former is nothing special, because the vehicles which pass the national route are increased by increasing the speed limit of the national route. The latter indicates that the current routing algorithm makes thin road readily traversable to the vehicle. Figure 23.6 shows that the loss function decrease with the decreasing the speed limit of the national route when the speed limit of the thin road is greater than 5 m/s. Otherwise the loss function is independent of the speed limit

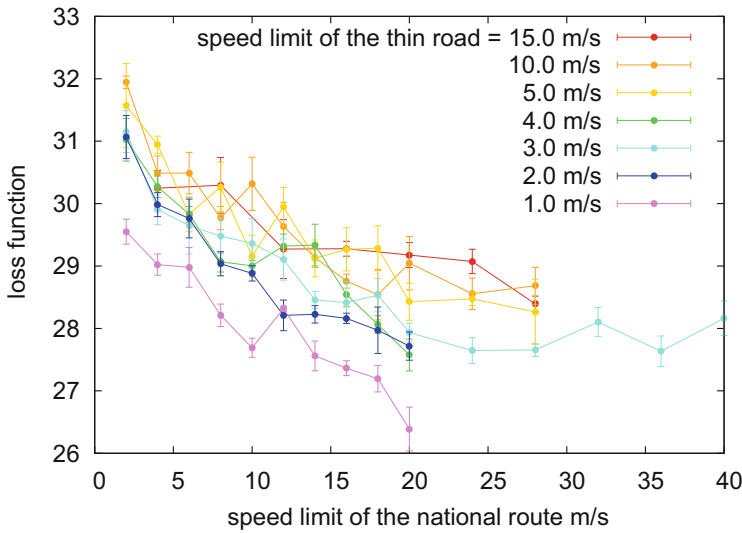


Fig. 23.5 The variation of the loss function $F_{\text{national route}}$, evaluated using Eq. (23.1), against a change in the speed limit of the national route at each value of the speed limit of the thin road

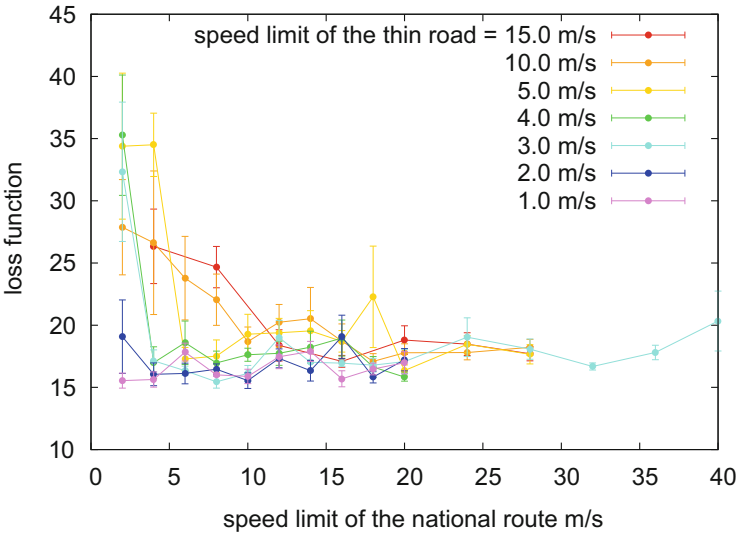


Fig. 23.6 The variation of the loss function $F_{\text{prefectural road}}$, evaluated using Eq. (23.1), against a change in the speed limit of the national route at each value of the speed limit of the thin road

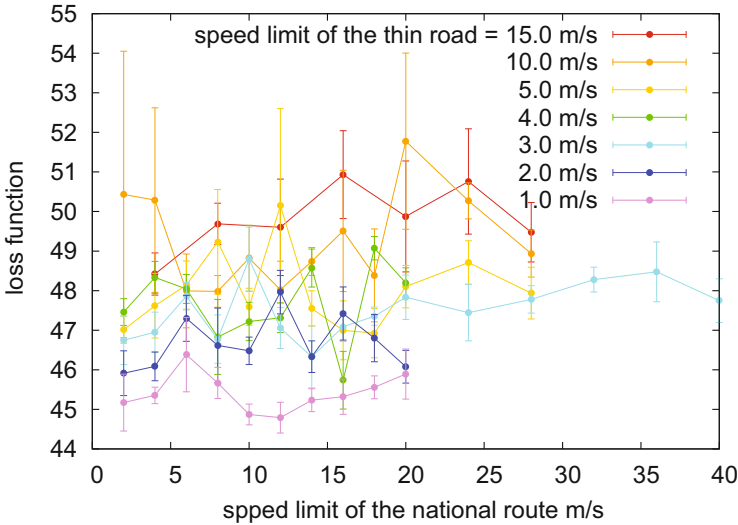


Fig. 23.7 The variation of the loss function $F_{\text{city road}}$, evaluated using Eq. (23.1), against a change in the speed limit of the national route at each value of the speed limit of the thin road

of the national route. Figure 23.7 shows that the loss function is independent of the speed limit of the national route, and slightly decrease with decreasing the speed limit of the thin road.

As seen from Figs. 23.5, 23.6, and 23.7, the value of the loss function is changed by varying the speed limit of the road. In these figures, the minimum values of the $F_{\text{national route}}/N_{\text{national route}}$, $F_{\text{prefectural road}}/N_{\text{prefectural road}}$, and $F_{\text{city road}}/N_{\text{city road}}$ are 0.68(1), 0.60(2), and 0.70(1), respectively. The number in parentheses indicates the accuracy of the last digit. To do the same adjustment with the speed limit of the other roads, the reproducibility will be better.

23.4 Summary

A traffic simulation of Kobe-city was performed using the SUMO whose map was constructed by high-quality digital map data provided by Zenrin Co. Ltd. Because there was no available data for the OD information, it was estimated from a geographical population distribution data. The traffic volume obtained by the simulation was compared with that of the traffic census data, and the result of the simulation is less than that of the traffic census data. In order to improve the reproducibility of the traffic census data, a parameter search whose adjustable parameter was chosen as the speed limit of the road was conducted. We found that this adjustment improved the reproducibility of the traffic census data. The reproducibility will be better by adjusting all of the road.

Further improvement of the reproducibility will need to reconsideration of the routing algorithm. Specific example is that, in the current routing algorithm, the national route and the thin road are indistinguishable. However, in real world, a driver should distinguish the individuality of the road.

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